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ABSTRACT

Students in three levels of high-school physics classes (advanced, regular, and general) were studied as they learned concepts about gravity, balanced forces, and projectile motion to examine the effect of text and instructional techniques, such as prediction and labs, on learning. Reading appeared to be an effective influence on learning information about projectile motion for advanced classes only, and other influences on learning, such as prediction and labs, were not effective. Analyses of observational and interview data suggest the following conclusions about why the instructional practices studied were ineffective: (1) students prefer to maintain their intuitive conceptions rather than undergo conceptual change; (2) students adopt a task-oriented rather than concept-oriented approach to laboratory explorations and other learning experiences; (3) students in the advanced classes had more resources for understanding counterintuitive concepts than students in regular/general classes; and (4) textual materials used in science classes could be improved. (Contains 24 references and 5 tables of data. Examples of test questions are attached.) (Author/RS)

High School Physics: The Role of Text in Learning Counterintuitive Information

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NRRC

National
Reading Research
Center

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Kim Lay is a science teacher at Clarke Central High School who taught physical science to ninth graders in Project Success. She prepared to become a teacher by earning an undergraduate degree in science education. She has taught biology and earth science in addition to physical science. Before coming to her present school, she taught life science to special education students as a subject matter expert in a special program. She is now working on a master's degree in special education with an emphasis in learning disabilities. She believes that her strength in teaching is that she can explain concepts in understandable language.

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High School Physics: The Role of Text in Learning Counterintuitive Information

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Abstract. *Students in three levels of classes were studied as they learned concepts about gravity, balanced forces, and projectile motion in order to examine the effect of text and instructional techniques, such as prediction and labs, on learning. Reading appeared to be an effective influence on learning of information about projectile motion for advanced classes only, and other influences on learning, such as prediction and labs, were not effective. The reasons for the ineffectiveness of texts, labs, and predictions were explored further through analysis of field notes, interviews, and student-generated protocols.*

Science educators sometimes recommend that text be eschewed in favor of hands-on learning experiences and discussion (e.g., Newport, 1990). However, textbook use is ubiquitous in science classrooms (Hynd, McNish, Qian, Keith, & Lay, 1994), and textbooks represent the most often used modes of presentation of content in both elementary and secondary schools (Schymansky, Yore, & Good, 1991; Yore, 1991). School districts may believe that textbooks help them meet their state objectives and accomplish their goals for science instruction. We anticipate that textbooks, because they are so prevalent now, will continue to be an accepted part of science classrooms for some time.

Textbooks in content subjects, however, have come under repeated attacks. For example, Beck, McKeown, and Gromoll (1989) analyzed social studies textbooks and found that such texts had many features that interfered with learning, including demands for prior information that students do not typically have, poor examples, and "seductive details" that draw the reader away from the main points (Garner, Gillingham, & White, 1989). Britton and Gulgoz (1991) have rewritten science texts because they have found that, in most cases, these texts require novices to make inferences that are difficult to make because of their lack of knowledge. Researchers who consider how texts can enhance learning for students may be

able to influence the production of better texts. For this reason, studying the way textbooks and other printed media affects students is vital.

Texts (including all forms of printed media) may be especially important when counterintuitive topics are studied. Learning is difficult when scientific principles contradict intuition, and teachers need to provide a variety of opportunities for students to overcome their intuitive conceptions. Hands-on learning experiences and discussion may not be enough. As Driver and Easley (1978) point out, explorations of the way the world works can fall short of producing accepted scientific understandings. For example, students often believe that objects of varying weights will fall at different rates because of an increased pull of gravity on heavier objects. Experiments comparing the free fall of objects varying in weight may even produce results consistent with this intuitive theory, because heavier objects do, sometimes, fall faster if not in a vacuum. Students who discuss the results of experimentation may decide that their original theory was correct.

Studies from reading education (Marshall, 1991; Hynd, McWhorter, Phares, & Suttles, 1994) and instructional design (Snyder, 1993) have shown that students in collaborative groups often convince each other of intuitive theories rather than help each other learn accepted scientific principles. The accepted scientific explanation for rate of descent, however, is that air resistance is responsible for the differing rates of free fall, not gravity. This principle is counterintuitive to many students, and, because it contradicts what seems reasonable, conceptual change in a scientific direction is difficult. Students reject new information, simply memorize it, incorporate information that fits into their existing cognitive structures, but rarely reconstruct old understandings to accommodate new ones (Hewson & Hewson, 1984).

Chinn and Brewer (1993) say that the processes students go through in maintaining their intuitive but nonscientific conceptions are similar to the processes engaged in by scientists. That is, when any individual is confronted with data that do not fit expectations, he/she (a) ignores it, (b) rejects it, (c) excludes it, saying it is not related, (d) holds it in abeyance, (e) reinterprets it to conform to expectation, or (f) makes minor conceptual changes. Rarely does an individual accept the data and change expectations in a substantive way.

Refutational text, however, has shown some success in convincing students to adopt scientific explanations of counterintuitive principles. Refutational text (see example in the Appendix) is text that attempts to elicit conceptual conflict by presenting the popular intuitive conception, explaining that the intuitive conception is wrong, and then describing the accepted scientific theory. As a part of the description of the accepted theory, the text attempts to convince readers of its plausibility and usefulness. Guzzetti, Snyder, Glass, and Gamas (1993), in a meta-analysis of intervention studies from both reading and science education, found this type of text to be effective in helping students overcome intuitive conceptions. Studies not included in the meta-analysis, moreover, have confirmed these texts' effectiveness in the long run, with gains from reading still evident as much as three

months after instruction (Hynd, Alvermann, & Qian, 1993; Hynd, McWhorter, Phares, & Suttles, 1994).

According to Posner, Strike, Hewson, and Gertzog (1982), in order for students to undergo conceptual change, they must be dissatisfied with their current explanations and find scientific explanations to be plausible, useful in helping them explain current phenomena, and have the potential to help them explain future phenomena. Well-written refutational texts would have the potential to elicit these characteristics. The studies of refutational text, however, have not been conducted in intact science classrooms. Whether or not refutational or other types of text are effective in more ecologically valid settings is still questionable.

The purpose of this study was to examine the role of text, including refutational text, in science classrooms in which teacher-initiated lecture/discussion, laboratory explorations, and group work were other forms of instruction. Is text, especially refutational text, effective in real classrooms and not just in contrived experiments? If so, what explains its effectiveness? Classrooms where the textbook is the only kind of instruction were not included, because this study explored the role of text as a support to constructivist learning environments. Of particular interest was whether text is useful when used as a type of advance organizer (Ausubel, 1968) for other sources of evidence such as exploration and discussion, or whether refutational text is useful when used as confirmation for learning that has already taken place with those activities. In short, the placement of text in a sequence of activities that includes exploration and socially shared knowledge seems important, but optimal sequences or ways to use text have not been found.

To help answer these questions, a tri-layered study of text and instruction in high school physics and physical science classes at advanced and lower levels of instruction was devised. In the first layer, sets of pre- and posttest data were collected in explorations of text and other instruction related to three topics: gravity, balanced forces, and projectile motion. The first of the three explorations was to study the effects of making a prediction before lab and reading a refutational or regular textbook passage about gravity after lab. It was our feeling that students who made predictions about the outcome of an experiment might be more likely to want to confirm or disconfirm their predictions, thereby learning more from the lab experiment and the text, while students who did not predict would not be so inclined and would learn less. However, an alternate outcome would be that students who predicted prior to an experiment would become committed to their predictions and would learn *less* from the lab and the text. Alvermann, Readence, & Smith (1985), indeed, provide evidence that, when a student's knowledge is solicited prior to reading, the effect on learning is debilitative. In that study, however, lab work was not the focus. The text manipulation in this first exploration was to determine if refutational text was more effective than regular text.

The purpose of the second exploration was to study the effects of reading either refutational or regular text before lecture, discussion, and lab or after lecture, discussion, and lab. If students learned more when they read text

before the lesson, that might mean that the text was acting as an advance organizer for later learning (Ausubel, 1968). If students learned more from reading text after the lesson, that might mean that the text provided a needed confirmation (or disconfirmation) of the information they had learned previously.

The purpose of the last exploration was to determine the effects of a conceptually based lab and reading. This exploration was developed with the belief that a well-planned lab that demonstrated to students the value of counterintuitive scientific explanations would cause students to learn more than students who did not participate in such a lab. An interaction between text and the lab was also anticipated; that is, students who participated in both would do better than students who participated in one only, and they would do better than students who participated in neither.

In all three explorations, it was assumed that students who did better on the posttests had gone through some sort of conceptual change. That is, they had changed intuitive but nonscientifically accepted ideas into accepted scientific theory. This was assumed because the true-false, short-answer, and application tests[1] used in this study elicited students' intuitive conceptions. All wrong answers on the true-false tests represented common, intuitive but nonscientific conceptions, and the short-answer and application questions focused on information that has been found in previous studies to be counterintuitive (e.g. Hynd, McNish et al., 1994). Furthermore, because no student made a perfect score on the test, it was assumed that even students who knew a lot of scientific information about the topics retained some intuitive but nonscientific ideas.

The second layer of this study was observational in nature. While students participated in lecture, discussion, and lab, university-based researchers observed and interacted with them as observer-participants. Students were asked to explain what they were doing and learning, and to discuss how they learned information. As documentation, field notes were written and answers to our questions were audiotaped and transcribed. The purpose for this observational layer was to provide supportive data for the quantitative portion of this study and to get a clearer view of what students understood from the texts and other instructional activities in this study.

The third layer of this study consisted of interviews. In order to find out students' ideas about textbooks and other printed material in science, students were asked, in semi-structured interviews, about the usefulness of text and other aspects of instruction, about their opinions of their textbooks and other texts they read, and about their suggestions for improving printed scientific information. Additionally, in the non-advanced classes, selected students explained, in a one-on-one setting, their current ideas about the counterintuitive topics (gravity, balanced forces, and projectile motion), read different texts, and revised, if they deemed necessary, their earlier explanations of the topics. The purpose of these additional tasks was to discover aspects of textual presentation that presented difficulties to lower-level

[1]Copies of these tests can be supplied by the first author of this study.

students, an inquiry prompted by their science teacher who had mentioned that reading science text was difficult for them.

Method

Participants

Participants were students enrolled in two classes of Advanced Physics (taught by a single teacher), one class of Regular Physical Science (taught by another teacher), and one class of General Physics Science (taught by the same teacher who taught Regular Physical Science). The two advanced classes had 21 and 18 students participating, respectively. They were eleventh and twelfth graders. Of the students interviewed, 45% (9 out of 20) were planning to be science majors in college. The other students had not decided or were going into other fields. On the whole, these students came from educated families. Of the 20 interviewed, only 1 student reported that a parent had not graduated from high school (a professional musician). Thirteen reported that their parents had advanced degrees. The regular physical science class had 18 students enrolled and was taken by ninth- or tenth-grade students who may or may not have been planning to attend college. The general class had 16 students enrolled and was taken by ninth-, tenth-, or eleventh-graders who were not planning to go to college.

Because of absences and class changes, different numbers of these students participated in different portions of the study. For example, 8 or fewer students attended the general physical science class each day, making it difficult to include all students. Only a handful of students (11) in the two classes were interviewed. They were the ones who reliably came to class on a daily basis. Bearing in mind that these students were more serious about education than students who did not reliably attend, approximately 30% of the students interviewed were planning on a career that would necessitate learning science. Only 3 students expressed no interest in college. Their parents were less educated than the parents of advanced students, with 8 out of the 11 students reporting that at least one parent did not receive a high school education.

The teachers were both experienced. The advanced physics teacher was new to the school district but had taught science for 3 years in another district. She was familiar with the idea that students had nonscientific conceptions about certain topics in physics and taught in a style meant to elicit conceptual conflict in students. For instance, she would pose a question, have students talk among themselves to devise an acceptable answer, discuss the possible answers, then explain scientific principles through lab and further discussion. She supplemented the textbook with lessons from Hewitt's *Conceptual Physics* (1987), because of the elaborate explanations of scientific principles on a conceptual level found in this book. Although mathematical problem-solving was an important element of her classes, she was concerned that students develop conceptual understandings. Laboratory explorations were an important part of classroom activities, and she expected students to gain conceptual understandings from them.

The teacher of the regular and general physical science classes had taught in the

school district for 2 years, with 6-years' prior science teaching experience. Like the advanced physics teacher, she was concerned that students develop conceptual understandings of the physics topics. Because of this concern, she, like the other teacher, provided many more opportunities for laboratory explorations than were required and also emphasized group work. Having participated previously in a study with the researchers, she was also familiar with the idea that some concepts in physics are counterintuitive. Because of her concern for the difficulty students had with reading science materials and performing mathematical problem solving tasks, she did not, as a rule, require a great deal of reading-to-learn or higher-level math in her classes. Students learned to perform mathematical functions required for basic calculations, read lab materials and information placed on the overhead projector about scientific principles, and wrote explanations and answers to questions, but were not required to read the textbook on a regular basis. She often referred to information in the textbook, and students used some of this information to develop answers to questions she asked, but she did not assign reading as homework or as an in-class activity.

Procedures

The first two layers of this study, (1) the quantitative explorations of students' learning about gravity, balanced forces, and projectile motion, and (2) the observation of students who participated in learning about these topics, were completed before interviews (the third layer of the study) were begun. Because the procedures for each topic were different, they will be explained separately.

Gravity. All students took three pretests about their knowledge of gravity. These three tests consisted of a 20-item true-false test, a short-answer test, and an application task (see Appendix). These tests had been used in a previous study (Hynd, McNish et al., 1994). For this exploration, half of the students were asked to predict what would happen if two objects of different weights and shapes were dropped at the same time from the same height. The other students were not required to make predictions. Students then participated in laboratory experiments in which they performed the drops. Students formed groups of 2 and 3 to perform the experiments, and students who had predicted were placed together in groups. (When students were assigned to a prediction/nonprediction condition, they were randomly assigned by group.) After performing the experiments, students were asked to write about their data and explain what they had discovered about gravity. Because the students were in different classes taught by two different teachers, the group activities varied somewhat. For instance, in the advanced classes, the teacher asked students to drop eggs in cartons, while students in the regular classes were asked to drop a ball, weights, and paper. However, students were asked to engage in the same *kind* of activity. All students then read one of two texts—a textbook passage and a refutational excerpt derived from Hewitt's *Conceptual Physics* about gravity. After a short buffer activity, students took the same three tests they had taken as pretests. The design of the gravity

exploration was two levels of prediction (prediction, no prediction) by two levels of text (refutational, regular).

While students were engaged in the group activities described above, a university-based researcher asked them to explain what they were doing, to describe what they found, and to explain what they thought about gravity. Lab sheets were retained by these researchers for further analysis.

Balanced forces. In this exploration, the order and type of student texts was studied in a two-by-two design (two levels of text [refutational, regular] and two levels of order [before instruction, after instruction]). Approximately half of the students in the study read either a refutational or regular passage on balanced forces before they participated in teacher-directed discussion and laboratory. The other half of the students read one of the two texts after participating in the same instruction. Again, the instruction was somewhat different in the advanced compared to the regular and general classes. However, both teachers emphasized that any action caused an equal and opposite reaction and related that principle to examples, such as the example that when you sit on a chair, you exert a downward force on the chair and the chair exerts an equal upward force upon you. Students were given pretests prior to instruction, consisting of a 20-item true-false test, a short-answer test, and an application task (see Appendix). These tests have also been described in the Hynd, McNish et al. (1994) study. A university-based researcher again observed students during lab and other work and asked students to explain what they were doing.

Projectile motion. In this final exploration, half of the students participated in laboratory experiments to test the path of a projectile launched in a horizontal direction. Students performed experiments where objects were launched horizontally and their paths were observed. The main difference between the advanced and regular/general classes' lab work was that, in the advanced classes, students were required to compute the point at which the object would come to rest. In the other two classes, the computation was not required. In all of the classes, the main point was that an object launched horizontally will travel horizontally at a constant speed at the same time that it is traveling vertically at an accelerated speed, with the resulting path being a parabola. After the laboratory experiments, students either read or did not read a refutational text. Therefore, the experiment consisted of a two-by-two design, with two levels of instruction (lab, no lab) and two levels of text (text, no text). As in the other two explorations, pre- and posttests consisting of true-false, short-answer, and application items were given (see Hynd, McNish et al., 1994, and Appendix). Students were again observed, questioned, and videotaped.

Interviews. In order to find out more information about the effect of texts on the high school students in this study, one university-based researcher interviewed 30 students from the four classes in a one-on-one situation. The interview was semi-structured. Students were asked about their career goals and their mother's and father's occupations. Furthermore, they were asked to rate and discuss their motivation for physics and to describe a time,

if they could, when the information they learned in physics went against their current thinking. They were also asked to rank order the helpfulness of teachers, laboratory explorations, texts, and other students in their learning of scientific information. Finally, after looking at their textbooks and other texts (including refutational), they were asked to comment on the helpfulness of textual materials and to make suggestions for improving their textbooks. The interviewer followed up interesting comments with requests for more information. Some of these interviews were audiotaped. However, the regular and general physical science students found the tape recorder distracting. Therefore, the audiotapes were discontinued and the interviewer merely took notes.

In the regular and general physical science classes, several students were asked to describe their ideas about one of the three topics, to read selected textual material, and to revise, if they deemed necessary, their earlier statements about the topic. If students did not end with scientifically accurate descriptions of the principle being studied, the interviewer directed students back to critical portions of the text and helped them comprehend the critical information, providing as little scaffolding as was necessary until the students could explain that principle on their own. Subsequently, students were asked to comment on the specific aspects of the texts they read that were helpful or confusing. In this way, the researcher hoped to analyze why these students appeared to have difficulty learning from text.

Data Analysis. The two lower-level physical science classes in our analysis of data were combined because of the small numbers of students who actually participated in the explorations in the regular and general-level physical science classes (due to absences and attrition). Both the independent and dependent variables were the same. These classes were taught by the same teacher, identical procedures were used, and the achievement level of the two classes was similar on the pretests. Still, the small numbers of students in these classes contributed to a lack of statistical power. Therefore, nonsignificant results should not necessarily be interpreted as lack of effect. For both the advanced and regular/basic classes, a separate Analysis of Covariance (ANCOVA) was computed for each of the three tests on each of the three topics (gravity, balanced forces, and projectile motion). The covariate for each ANCOVA was the appropriate pretest. That is, for the true-false gravity posttest, the covariate was the true-false gravity pretest; for the short-answer gravity posttest, the covariate was the short-answer gravity pretest; and so on.

With the observational and interview data, constant comparison (Glaser & Strauss, 1967) was used to determine categories of information and emergent themes. Data were tabulated, if possible. Categories and themes used in this study were discussed with students and teachers, who were asked to comment on veracity.

Results

Quantitative Analysis

Two-by-two ANCOVAs were used to test the effects of the two levels of prediction (prediction, no prediction) and two levels of

Table 1. Means and standard deviations of gravity posttests

	True-False		Short Answer		Application		*N*
Advanced							
Text							
Refutational	16.58	(2.35)	6.16	(1.13)	1.05	(0.91)	19
Regular	14.93	(3.19)	5.47	(0.87)	0.87	(0.96)	15
Prediction							
Prediction	15.59	(2.91)	5.35	(0.85)	0.94	(0.94)	17
No prediction	16.12	(2.81)	6.35	(1.15)	1.00	(0.65)	17
Refutational/prediction	16.10	(2.26)	5.40	(0.80)	0.70	(0.90)	10
Refutational/no prediction	17.11	(2.33)	7.00	(1.33)	1.44	(0.92)	9
Regular/prediction	14.86	(3.52)	5.29	(0.88)	1.29	(0.88)	7
Regular/no prediction	15.00	(2.87)	5.63	(0.86)	0.50	(0.87)	8
Regular/General							
Text							
Refutational	10.42	(2.14)	4.50	(1.08)	0.75	(0.72)	11
Regular	11.90	(3.14)	3.70	(1.73)	0.70	(0.78)	10
Prediction							
Prediction	11.17	(2.02)	3.58	(1.50)	0.75	(0.72)	11
No prediction	11.00	(3.44)	4.80	(1.17)	0.70	(0.78)	10
Refutational/prediction	10.33	(1.67)	4.17	(0.75)	0.69	(0.75)	5
Refutational/no prediction	10.50	(2.43)	4.83	(1.21)	0.83	(0.69)	6
Regular/prediction	12.00	(1.83)	3.00	(1.73)	0.83	(0.69)	6
Regular/no prediction	11.75	(4[illegible]4)	4.75	(1.09)	0.50	(0.87)	4

text (refutational text, regular text) on students' performance on the gravity true-false, short-answer, and application posttests. The results are as follows.

In the advanced classes, there was a significant main effect for prediction on the short-answer test ($F_{1,32} = 4.02$, $p = .05$). Students who predicted the outcome of the laboratory did worse on the posttest ($M = 5.35$) than students who did not make predictions ($M = 6.35$). All other analyses were nonsignificant. In the regular/general classes, a main effect for prediction on the short-answer test was not significant ($F_{1,20} = 3.822$, $p = .08$). Students who predicted did no worse on the posttest ($M = 3.58$) than students who did not predict ($M = 4.80$). All other main and interaction effects were nonsignificant. Means are presented in Table 1. The single biggest factor in posttest performance appeared to be performance on the pretest. For example, in the advanced classes, the effect of the pretest was significant on the application task ($F_{1,33} = 32.11$, $p < .0001$). For the regular/general students, the pretest had a significant effect on the true-false test ($F_{1,20} = 16.46$, $p = .001$) and the

Table 2. Means and standard deviations of balanced forces posttests

	True-False		Short Answer		Application		N
Advanced							
Text							
Refutational	18.26	(1.29)	7.71	(1.16)	2.64	(1.34)	14
Regular	18.29	(0.93)	8.31	(0.85)	3.06	(0.97)	16
Order							
Before	18.09	(1.29)	8.00	(1.00)	2.71	(1.16)	14
After	18.38	(1.65)	8.06	(1.09)	3.00	(1.17)	16
Refutational/before	17.80	(1.63)	7.33	(1.11)	2.50	(1.38)	6
Refutational/after	18.50	(2.12)	8.00	(1.12)	2.75	(1.30)	8
Regular/before	18.33	(0.86)	8.50	(0.50)	2.88	(0.93)	8
Regular/after	18.25	(0.97)	8.13	(1.05)	3.25	(0.97)	8
Regular/General							
Text							
Refutational	14.29	(3.65)	5.43	(2.87)	1.86	(0.70)	7
Regular	11.44	(3.72)	3.89	(2.08)	1.56	(0.83)	9
Order							
Before	13.14	(4.26)	4.71	(2.96)	2.14	(0.99)	7
After	12.33	(3.65)	4.44	(2.22)	1.33	(0.47)	9
Refutational/before	13.67	(1.41)	6.00	(2.94)	2.33	(0.94)	3
Refutational/after	14.75	(2.89)	5.00	(2.74)	1.50	(0.50)	4
Regular/before	12.75	(3.90)	3.75	(2.58)	2.00	(1.00)	4
Regular/after	10.40	(3.20)	4.00	(1.55)	1.20	(0.40)	5

short-answer test ($F_{1,20} = 20.06, p < .0001$). Students who did better on the pretests did better on the posttests.

In the balanced forces exploration, 2 × 2 ANCOVAs were used to analyze the effects of the two levels of text (refutational, regular) and two orders of textual presentation (before and after instruction) on the true-false, short-answer, and application posttests. There were no significant main or interaction effects on any analysis of any of the posttests. Means are reported in Table 2. Evidently, it made no difference whether students read a refutational or a regular text or whether they read a text before or after instruction. Again, students who did better on the pretests did better on the posttests. In the advanced classes, the pretest had a significant effect on performance on the short-answer posttest ($F_{1,28} = 5.46, p = .03$) and the application task ($F_{1,28} = 4.19, p = .05$). In the regular/general classes, the pretest also had a significant effect on performance on the short-answer posttest ($F_{1,14} = 13.45, p = .004$) and the application task ($F_{1,14} = 8.96, p = .01$).

In the projectile motion exploration, 2 × 2 ANCOVAs were used to analyze the effects of the two levels of lab (lab, no lab) and the two levels of text (text, no text). There was a

Table 3. Means and standard deviations of projectile motion posttests

	True-False		Short Answer		Application		N
Advanced							
Text							
Text	18.75	(1.93)	6.19	(1.13)	2.25	(0.85)	16
No Text	16.93	(1.66)	5.21	(1.82)	1.79	(0.94)	14
Lab							
Lab	18.27	(1.77)	5.67	(1.36)	2.07	(0.85)	15
No Lab	17.53	(2.02)	5.80	(1.72)	2.00	(0.97)	15
Text/lab	19.13	(1.36)	6.13	(1.05)	2.38	(0.70)	8
Text/no lab	18.38	(2.39)	6.25	(1.20)	2.13	(0.93)	8
No text/lab	17.29	(1.67)	5.14	(1.55)	1.71	(0.88)	7
No text/no lab	16.57	(1.48)	5.29	(2.05)	1.86	(0.99)	7
Regular/General							
Text							
Text	12.38	(2.34)	2.50	(2.29)	0.88	(0.60)	8
No Text	12.25	(2.87)	3.08	(1.56)	0.67	(0.50)	10
Lab							
Lab	12.80	(2.44)	2.80	(1.39)	0.80	(0.70)	8
No Lab	11.80	(2.82)	2.90	(2.17)	0.70	(0.46)	10
Text/lab	13.25	(2.86)	2.00	(1.58)	1.00	(0.71)	4
Text/no lab	11.50	(1.12)	3.00	(2.74)	0.75	(0.43)	4
No text/lab	12.50	(1.30)	3.33	(1.12)	0.67	(0.43)	4
No text/no lab	12.00	(3.50)	2.83	(1.67)	0.67	(0.47)	6

significant main effect for text on the true-false posttest ($F_{1,28} = 4.63, p = .04$) in the advanced class. Students who read the text did significantly better ($M = 18.75$) on the true-false posttest than students who did not read the text ($M = 16.93$). All other analyses were nonsignificant. Means are reported in Table 3. Apparently, neither the lab nor the text caused students to learn more in the regular/general classes. In the advanced classes, the lab had no effect. As in the previous two explorations, students who did better on pretests did better on the posttests. In the advanced classes, pretest performance had a significant effect on posttest performance on the short-answer test ($F_{1,28} = 7.88, p = .01$). In the regular/general classes, pretest performance also affected performance on the short-answer posttest ($F_{1,18} = 11.34, p = .004$).

Because of the extremely small numbers of participants and the subsequent lack of statistical power, not much can be said in this quantitative portion of the study about the effects of variables that were statistically nonsignificant. For instance, because of the lack of power, it was not possible to determine whether order of textual presentation, before (as an advance organizer) or after (as confirmation),

made any difference in students' learning of counterintuitive ideas.

In looking at the means, however, the extremely small differences in groups who participated or did not participate in laboratory explorations are striking. Also noteworthy are the extremely small differences in groups who read or did not read text, or who read different kinds of texts in the regular/general classes. The qualitative data help explain the apparent lack of effectiveness of lab for both advanced and regular/general classes and text for the regular/general classes in producing conceptual change.

As for the significant results, predicting the outcome of a lab actually debilitated students' ability to undergo conceptual change. This result supports the work of Alvermann, Readence, & Smith (1985) who concluded that, when intuitive conceptions are activated prior to reading, students may become committed to their intuitive conceptions and not be swayed by text. In this study, students, perhaps, became committed to their predictions, so they did not interpret laboratory data in scientific ways. The lab results were meant to cause students to feel conflict between their current understandings and scientific principles. It appears that, rather than feel conflicted, students may have reinterpreted data from the lab to fit their current ideas. Again, qualitative results help explain this phenomena.

In the advanced classes, reading a text helped students undergo conceptual change about projectile motion on the true-false posttest, while the projectile motion lab did nothing to change their conceptions. Apparently, in some cases, reading a text can enhance the learning of counterintuitive ideas. This finding corroborates other studies showing that text, particularly refutational text, is effective. However, it is disconcerting that, in other cases, refutational text was no more effective than regular text in helping students develop scientific understandings.

Although it is not surprising that students who began the study knowing more scientific information did better on the posttest, the quantitative results enhance the notion that, when intuitive ideas run counter to scientific theory, learning is incremental in nature. That is, students who began the study with many nonscientific conceptions did not, by and large, end the study with full scientific understanding. Rather, students who knew a lot learned a little more, and students who knew a little also learned a little more.

Other Analyses

In this section, other results that help explain the quantitative results of the study are reported. The first question arising from quantitative data is: why is laboratory exploration (including prediction of lab outcome) so seemingly ineffective? To answer this question, laboratory worksheets and our fieldnotes about laboratory work from the two class levels were analyzed. When applicable, we tabulated answers in various categories. The second question addresses the students' reading.

Laboratory explorations: regular/general classes. Students in the regular/general classes who participated in a prediction/no prediction exploration of gravity were the first lab analyzed. Half of the students were asked to

predict what would happen if a heavy object (bag of clothespins) and a light object (single clothespin) were dropped at the same time from the same height. The other half of the students did not predict. Then, all students participated in a lab where they dropped two objects that were different in weight and shape (a weight and an eraser), two objects that were different in shape but weighed the same (a wadded up and flat piece of paper), and two objects that were similar in shape but were different in weight (a 50 kg weight and a 100 kg weight). After students dropped each of the items from the same height at the same time in three trials, they recorded their observations and wrote down explanations for their findings.

Of the 17 students who made predictions, 6 predicted that the bag of clothespins would reach the ground at the same time as a single clothespin, but only 4 offered a scientific explanation (i.e., that gravity pulls objects at the same rate of acceleration regardless of weight). Nine students predicted that the bag of clothespins would hit first because it was heavier, and 2 students predicted that the single clothespin would hit first because it was lighter. Only 13 of the 17 "prediction" students actually participated in the laboratory explorations, and 15 students participated who had not made predictions. Of concern was whether or not students would perform the trials in a way that would allow them to actually observe the expected scientific outcome. Students in both prediction and nonprediction groups ($N = 31$) did make correct observations 82% of the time; the tendency to make correct observations was slightly lower for the prediction group (79%) than the nonprediction group (84%). Only 21% of the prediction group's explanations and 22% of the nonprediction group's explanations were scientifically accurate, however. Even though students observed that objects differing in weight and shape fell at the same time, only 5 out of the 31 students (16%) could explain why. Six students said they did not know or merely reiterated their observations (i.e., they fell at the same time). Other students did not give enough information to score or gave nonsensical explanations, such as "the two objects have different weights."

Although most students (96%) observed that a wadded piece of paper falls faster than a flat one, only 7 out of 28 students (25%) attributed the phenomenon to air resistance. Twenty-one students said that the wadded piece of paper was heavier, even though they had weighed both pieces of paper previously and found them to be the same weight. When the two differing weights were dropped, even though 21 out of 28 students (75%) correctly observed that the weights fell at the same time, only 6 of those 21 (29%) provided a scientific explanation. Other students did not explain or gave nonsensical answers, such as "air made the weights decrease in speed" or "the heavy and light weights weighed the same." One student said that the heavier weight "decided not to use all of its gravity."

The answers of students who had made correct predictions prior to the lab were analyzed. Of the 4 students who predicted correctly, only 3 completed the lab work. Each of the 3 made correct observations only 67% of the time, and none wrote a scientifically viable explanation for any of their observations. It is possible that the lab ended up being

more confusing than helpful to them. Overall, the prediction activity in particular and the lab in general may have allowed students' intuitive conceptions to solidify because they could not explain their observations.

Field notes indicate that, in this lab, students who worked together often copied each others' explanations, even when the explanations did not make sense. Rather than discuss explanations with each other, they would merely ask what the other person wrote and then write the same thing. This behavior suggests students were interested in completing the task more than they were in understanding it. It may also reflect students' sense of confusion about gravity. When they encountered phenomena that went against their intuition, rather than pay attention to it, they may have merely ignored it, preferring to engage in task completion rather than working arduously through their confusions.

Researchers observed that the students expended much of their lab time weighing the materials before dropping them. In one case, the lab students took 15 min to weigh correctly and record the objects for the first trial. Another group failed to record the weight of items, so that when the students dropped them, they had to weigh them again to see which one was heaviest. Working the spring scale correctly became an end to the lab itself, rather than a means to achieving conceptual understanding. In addition, while students were weighing and dropping materials, they would often talk about personal matters. At one point, a whole class began talking about the outcome of a sports event, with the teacher joining in the conversation. Obviously, the majority of students, whether or not they predicted, were not concentrating on conceptual understandings.

Did students learn anything about gravity from instruction? Of the 23 students who completed both pre- and posttests, 18 (78%) improved their scores. Ten of the 11 students (91%) who predicted before the lab and took a posttest improved, and 8 out of 12 students (67%) who did not predict improved their scores. Of course, students also read and discussed gravity with their teacher. Therefore, it can be assumed that learning occurred because of other variables in addition to or besides the lab. The teachers' lessons or students' reading may have accounted for this improvement, although the effect of reading was not statistically significant.

In another lab in the regular and general classes, the teacher asked students to participate in a lab on projectile motion. The purpose of this lab was to get students to understand that an object launched in a horizontal direction into the air has not only a horizontal direction due to its momentum, but also a vertical direction due to the force of gravity. The two movements operate independently. That is, in the horizontal direction, an object moves at a constant speed because it is no longer being acted on by a force. In the vertical direction, the object moves at an accelerating speed due to the force of gravity. The resultant direction of the object is parabolic. The independence of momentum and gravity means that, if an object is launched horizontally, it will hit the ground at the same time as an object that is dropped from the same height. Gravity is pulling both objects to the earth at the same accelerating speed, even though one is traveling some

distance horizontally before it reaches the ground. This concept is counterintuitive to most students. They believe that one of the objects would hit the ground sooner than the other.

The laboratory exploration consisted of three parts. In the first part, the laboratory directions asked students to predict where an object carried and dropped by a moving person would fall—in front of, on, or behind the release point. Students were also asked to explain their answer. The laboratory directions then asked students to walk past a line with an eraser and to drop the eraser as they crossed the line. Students performed 5 trials. After they recorded the results of each trial, students noted whether their predictions were correct and provided an explanation of their results. The laboratory directions then asked students to perform the same experiment (5 times) with a flat piece of paper and to record their results and explanations.

In the second part of the exploration, students were asked to predict and explain where a suction-cupped dart would land—on or below a target—if they fired it from a dart gun from the exact height as the target. Again, they were asked to explain their predictions, perform the experiment (5 times from two steps back and 5 times from four steps back from the target), and to record and explain their results.

In the third part of the exploration, students were asked to drop and fire a dart at the same time from the same height. An observer noted the time the darts hit the ground. Prior to the experiment, students were asked to predict when the darts would hit (same time, dropped dart first, or shot dart first) and to explain their predictions. After the experiment (performed 5 times), they were asked to note if their predictions were correct and to explain their findings.

Half (12) of the students in the two classes participated in this lab. Half of the students did puzzle activities that were meant to control for time but not contribute to students' knowledge of projectile motion. To make sure that students followed directions and performed the experiments in a way in which they would observe scientifically expected outcomes, the teacher and two university-based researchers worked with groups. Students were not told what to write or that their observations were wrong. The purpose of adult participation was to make sure that students did not have difficulty with procedures, in the hope that they would be more likely to pay attention to their conceptual understandings.

How did students who participated in the labs perform? Of the 12 students who participated in the lab, 6 of them (50%) predicted correctly that a carried and dropped object would fall in front of the release point, but only 3 (25%) could explain correctly why this would happen. The other students believed that the object would land in front because it would roll or bounce once it hit the ground, or did not give an explanation. Nine students (75%) actually observed during experimentation that an eraser would fall in front of the release point, and 3 of the 6 students who predicted wrongly acknowledged that they had made the wrong prediction.

Students' explanations of the results, however, were similar to the explanations for their predictions. Only 3 students (25%) correctly explained why the eraser fell in front of the

release point (2 students who had explained their predictions correctly and 1 who had not explained his prediction). The others explained that the eraser fell where they dropped it (2), said that the eraser rolled or bounced (4), simply restated the findings (that the eraser fell in front of the line) (2), or did not answer (1). When asked to observe and explain what happened when a flat piece of paper was dropped in the same type of experiment, all 12 of the students (100%) observed that the flat piece of paper behaved differently than the eraser in that it floated to the ground, often falling behind the release point. Only 3 students (25%) correctly explained that air resistance was responsible for the difference, however. Only 1 of the 3 correctly explained the eraser's movement. The other 9 students (75%) explained that the paper weighed less than the eraser (6), merely described the results (2), or did not answer (1).

In the second portion of the lab, students were asked to predict where a shot dart would hit a wall, at the point where it was shot or below the point. Nine students (75%) made the correct prediction that the dart would hit below, but no one gave a scientific explanation of why that would happen. Students either described the dart's path (it will fall below) (4) or said that the gun would not be aimed correctly. When asked to perform the task, 9 students (75%) observed that the dart hit the wall below the point where it was shot. Again, no student could provide a scientific explanation of why it happened. Rather, students explained their observations in the same way that they described their predictions.

In the last portion of the lab, students were asked to predict when two darts—one shot forward and one dropped from the same height at the same time—would hit the ground. Only one student predicted correctly that the two darts would land at the same time, but he did not have a scientific explanation. He explained that the two darts had the "same pressure." Four of the students predicted that the shot dart would reach the ground first because it had more power and was faster. Seven students predicted that the dropped dart would reach the ground first, some explaining that the shot dart had more power and would go farther (4). One of these students also explained that the momentum of the shot dart would slow down, making it hit the ground last. Three students explained that the dropped dart had a direct route to the ground, whereas the shot dart did not.

This experiment was harder to perform without error, and it was harder to observe whether or not the two darts hit the ground at the same time. Therefore, only 6 of the students (50%) observed the scientifically expected outcome. Other students observed that the dropped dart hit first. No student explained scientifically why the darts should land at the same time. Even the students who observed the scientific outcome had explanations similar to their original predictions—that the shot or dropped dart had more power. One student decided that they hit at the same time because of air resistance.

It can be concluded, then, that the students saw what they believed they would see (as in the shot and dropped dart experiment) or saw scientifically expected outcomes that, because

they could not explain them, they ignored. Students' explanations after experiments were mostly the same as the explanations they had given before experiments. Very little, if any, conceptual gain from the lab was observed.

The next day, the teacher presented a lesson in which she talked about the principles students explored during the lab. Because all students heard the lesson, even those who had not participated in the lab, the teacher did not directly mention the lab experiments. However, she did mention every concept covered in the lab, using the same examples in the same order. She asked students what would happen to objects in various similar situations and what their explanations would be, then immediately discussed the scientific outcome and explanation. At this point, 1 student in the regular class who had participated in the lab insisted that an arrow that was dropped would land before an arrow that was shot. However, he was the only one who questioned the teacher's explanation.

It was believed that students who had participated in the lab would then be able to make sense of their observations and understand the results of their experiments. Did the lesson help these students more than it helped the students who had not participated in the lab? The answer is "no." The only data available are posttest results (after reading); but in this group, reading did not make a difference. Of the students who participated in the lab and took the posttest (only 10 students), 7 (70%) improved their scores on the three posttests when compared with the pretest, while 3 (30%) did not improve. Of the 11 students who did *not* participate in the lab but only heard the lesson, 9 (82%) improved their scores while 2 (18%) did not. As mentioned previously, the effect of lab was not significant when statistically tested. The majority of students did appear to gain conceptual understanding of projectile motion, whether or not they participated in a lab or read a text. The teacher's lesson may have been largely responsible for this gain.

Because students worked together in groups, the question of whether the individuals in these groups ended up with similar explanations and understandings of their labs was addressed. In these experiments, the responses of students who worked together were different in 80% of the cases and the same in only 20% of the cases. This is because, while students had similar observations, they did not discuss their reasons together (even though they were directed to do so). For some reason, they did not copy each others' explanations as in the first lab, possibly because a teacher or researcher was observing them.

Our interviews may help explain why these students did not consult each other for explanations. Students were asked to rank order the teacher's lessons, the text, the lab, and other students as to their helpfulness in learning scientific principles (see Table 4). Of the 10 people who answered this question in these classes, no one ranked students first, 1 ranked students second (10%), 3 ranked students third (30%), and 6 ranked them last (60%). Those who ranked students last explained that the other students were not helpful at all, they did not know anything, and they kept individuals from doing their work. Students often commented about how it was necessary to ignore

Table 4. Ratings of instructional factors

	1st	2nd	3rd	4th
Advanced				
Text	3 (17%)	2 (11%)	7 (41%)	6 (32%)
Teacher	6 (33%)	7 (39%)	1 (6%)	4 (21%)
Lab	7 (39%)	2 (11%)	5 (29%)	4 (21%)
Students	2 (11%)	7 (39%)	4 (24%)	5 (26%)
Regular/General				
Text	3 (30%)	4 (40%)	3 (30%)	1 (10%)
Teacher	6 (60%)	3 (30%)	1 (10%)	0 (00%)
Lab	1 (10%)	2 (20%)	3 (30%)	3 (30%)
Students	0 (00%)	1 (10%)	3 (30%)	6 (60%)

other students in class and to pay attention, because other students could get them into trouble. Lab fared only slightly better. One student ranked lab first, 2 ranked it second, 3 ranked it third, and 3 ranked it fourth. Although several students said they liked the labs and found them motivating, they were apparently not as helpful as the teacher or the text, which were ranked higher.

Laboratory explorations: advanced classes. The lab results in the advanced physics classes were also analyzed. The first lab we observed was the gravity lab. The laboratory materials directed students to design a carton for an egg that had similar dimensions to other cartons in class, but that would allow an egg dropped from a third-story window to fall to the ground unbroken. Prior to the lab, half of the students were asked to predict how fast their carton would fall in relation to others. Students dropped their eggs out of the second-story window and timed the drop. They then compared their times with that of other students, and calculated the distance and mass. Students explained their observations on the lab sheet.

Of the 16 students who made predictions, 4 (25%) were scientifically accurate (i.e., that all cartons would fall in approximately the same amount of time, without air resistance). Of those 4, 3 interpreted the data scientifically, while 1 did not include enough information to score. Twelve students (75%) failed to make scientific predictions. Either they did not predict (6) or they said that the heavier cartons would fall faster. One person said the lighter carton would fall faster. Of the 12 students who made nonscientific predictions, 2 (17%) interpreted the data correctly, saying that the cartons traveled at essentially the same speed, regardless of mass. There was a total of 11 out of 16 (69%) nonscientific explanations for the data. Students most often said that the larger the mass, the faster objects would fall (6), even when saying so meant that they ignored data. Students who mentioned that the data did not support their interpretation said that human

error accounted for the variations in falling time.

Essentially the same behavior was observed for students who did not predict. Four out of 16 students (25%) interpreted data correctly, while 12 (75%) did not. All 12 of the students equated larger masses with faster falls, even though they had to ignore the data to say so or explain it by human error. One student explained, "The more mass a container has, the faster it should fall. However, L's container defies this idea, so I can only observe that this case must be one of extreme error."

By the time students took the posttest, however, most had improved their pretest scores, indicating that they had at least worked through some of their intuitive conceptions. Of the prediction group, 8 out of 13 (62%) taking the posttests had improved their scores. Of the nonprediction group 11 of the 14 (79%) taking the posttests had improved their scores. Since neither the prediction activity nor the reading accounted for improved scores, statistically, perhaps the teacher's lessons made a difference. In the case of gravity, however, it is likely that knowledgeable students helped others learn scientific principles. In field notes, the following scene is described.

> M. B. (male advanced physics student) walks into class the day of the projectile lab experiment with an egg in a carton. He has those around him hold the carton and brags that his is going to break for sure because he has made it so heavy that it will travel faster than anyone else's egg. He says that he put nails in the bottom to weigh it down. At this point, no one tells him he is wrong. When he performs the drop and compares his time with the time of others, he expresses consternation that his carton did not fall faster.
>
> (The following week.) Today, M. B. mentions that heavier objects fall faster and two other students at his table chide him. They tell him it's not true. He argues at first, almost getting mad at his fellow students and then becomes quiet. When he completes his labsheet, he says of his data, ". . . time is affected by the mass," essentially not dealing with the discrepancy between this idea and his lab observations.
>
> (Several days later.) Students are performing an experiment where a metal and a wooden ball accelerate down a ramp. Another student in M. B.'s group, W. Y., says that he doesn't understand how the metal and wooden ball can accelerate at nearly the same speed when they differ in weight. M. B. is the first to tell him that he should know that gravity affects all objects equally, regardless of weight. W. Y. says, "I know the rule, I just don't understand why." The teacher at that point mentions that a portion of the text that others read explains why. Another student at the same table says, "Yeah. I remember it," and still others chime in. The teacher gets him a copy of the text to read.

In this example, M. B. may have come to doubt his idea about gravity when his experiment did not go as he had planned, but he was not willing to relinquish it (at least publicly) until other students instructed him. He, in turn, instructed another student who did not under-

stand the scientific explanation. There were several students in the class who were regarded as very knowledgeable about physics. As one student commented, "If you need to know something, just ask. . . ." If these students explained a scientific principle, the others usually listened. M. B., likewise, acquiesced to their expertise.

When the advanced students were asked to rank order the teacher, the text, the lab, and other students, other students ranked higher than the regular/general students had ranked them. Of the 18 students who were interviewed, 2 ranked students first (11%), 7 ranked them second (39%), 4 ranked them third (22%), and 5 ranked them last (28%) (see Table 4). When asked to explain the rankings, only 1 student mentioned that some students did not know anything. Others simply said that other aspects of the class helped more. As for the labs, 7 students ranked them first (39%), 2 ranked them second (11%), 5 ranked them third (28%), and 4 ranked them fourth (22%). Students who did not like labs said that they only demonstrated what they already knew. One student said that it would be better if they made up their own labs. Students who liked the labs said they could understand concepts better when there were hands-on experiences.

By the time these advanced students participated in the projectile motion lab, they had perfected the tendency to attribute uninterpretable data to human error. In their projectile motion lab, they hurled a metal ball down a ramp, leaving space on the table for it to travel horizontally for a short distance before leaving the table and falling to the ground. Their task was to figure out where the ball would fall. To figure this out, students needed to know that the horizontal motion represented a constant speed, that the vertical motion represented an accelerating speed, and that the resultant path of the metal ball would be a parabola. Students could calculate the time it would take for the ball to hit the ground if they knew how to calculate vertical speed as a function of acceleration due to gravity, and they could calculate how far forward the ball would go if they knew the time it would take to hit the ground.

All of the students could perform the calculations, but the labs were another matter. Students calculated, measured, and placed a cup on the floor at the point where they thought they could catch the ball, based on their calculations. When the ball failed to hit the cup as they had planned, 3 of 4 observed groups gave up a systematic approach and began to place the cup at varying points until the ball hit the cup. At that point, they used the distance to help them figure out the other calculations. When the researcher asked them why they were doing it that way, all groups said that there was too much error in their timing, so their calculations would always be off. The lab ended up neither reinforcing nor negating their ideas about projectile motion, because students were not thinking about the lab on a conceptual level; they were merely trying to get the calculations right.

The advanced students, then, like the regular/general students, failed to learn from laboratory explorations because they saw what they expected to see, ignored data that did not fit in with their perceptions, explained away data as erroneous, and failed to confront data conceptually. Students' learning in both ad-

vanced and regular/general classes can be explained as at least partially the result of the teacher's lessons rather than the lab. In the advanced classes, students learned from other students as well. This was not the case in the regular/general classes. The quantitative results also indicated the effectiveness of reading for the advanced but not the regular/general classes. Thus, advanced students had avenues for learning that the regular/general students did not have.

Students' reading. The second question arising out of the quantitative analysis is: why did reading a text have such little effect on the regular/general physical science students and minimal effect on the advanced students? To answer this question, students' comments about the helpfulness of various aspects of the class, including the text, and interview data where students were asked to read and explain texts dealing with gravity, balanced forces, and projectile motion were analyzed.

As previously mentioned, selected students in both the advanced and regular/general classes were asked to rank order the teacher, the text, labs, and other students as to their helpfulness in learning physics concepts. In the advanced classes, the text did not fare as well as the teacher, labs, or other students.

Three students ranked the text first (17%), 2 ranked it second (11%), 7 ranked it third (38%), and 6 ranked it last (33%). These students said that their textbook was out of date, and many offered suggestions for improving it. The most common suggestion was that the textbook needed better explanations of concepts and formulas. Twenty out of 31 (65%) of the suggestions mentioned better, more detailed explanations and examples. Five of these students specifically mentioned that the textbooks failed to take into account their prior knowledge. One student said, "It assumes that you know what a math problem means. It doesn't explain concepts. It's sort of like missing the foundation of the house. When I read it, I feel like I'm floating in air." Three students said that the text was not as good as a teacher, because questions could not get answered. One student offered the suggestion that the textbook authors list commonly asked questions and provide the answers at the end of each chapter. Several students said that the textbook needed to be more in touch with the interests of high school students and to match the language and examples to the students' styles and interests.

Other students said they would like to see a better-organized text with more study aids (11 out of 31 comments, or 35%). Five students suggested that textbooks use highlighting, boldfaced terms, and more illustrations and diagrams. Six students felt that the formulas and sample problems should be in a central location that was keyed to explanations and derivations. That is, they wanted to be able to look at a formula, read an explanation of what it means and how it is derived, and see sample problems using the formula, without having to thumb through the book searching for information.

When asked what strategies they used to help them learn physics, only 6 students said they read (18% of the comments). What they did besides read was listen carefully, take notes, think critically about information, try to understand concepts, and ask questions (41% of

Table 5. Ratings of motivation

	Low	Average	High	Extrinsic	Intrinsic
Advanced	2 (11%)	5 (26%)	12 (63%)	7 (30%)	16 (70%)
Regular	1 (9%)	1 (9%)	9 (82%)	5 (45%)	8 (55%)

the comments). They also completed assigned problems (15%) and studied illustrations and text (24%). Several students expressed frustration with their textbook. One student said, "I don't mess with the textbook. It's confusing." Another student commented, "I should be telling you that the text is the best way to learn information. I would tell you that about all of my other classes. I learn by reading, and I read a lot. I just can't understand this textbook. It's way above my head."

Nineteen students were asked to compare their regular textbook with naturally occurring, refutational passages from Hewitt's *Conceptual Physics*. Seventeen students (90%) preferred the *Conceptual Physics* passages because, they said, these passages explained the concepts in more detail and because the illustrations, diagrams, examples, and questions were better. These students appeared to be interested in learning from reading but hungry for better-written explanations of the physics concepts they did not understand.

To further explore this notion, which implies some sort of intrinsic motivation, students were asked to rate their motivation on a 1 to 10 scale, with 1 being low and 10 being high (see Table 5).

Most students rated their motivation as high. When asked to explain their reasons, 7 out of 19 (30% of the comments) discussed extrinsic factors such as grades, while 16 out of 19 (67% of the comments) discussed intrinsic factors such as enjoyment in learning, wanting to use the principles to understand life, or being interested in learning about certain topics. (Note that some students described both intrinsic and extrinsic motivation.) Even when they had rated their motivation as negative, 4 students explained that they were not motivated because they could not understand or did not like physics, indicating that intrinsic factors were important to their motivation. Two students specifically said that they would be more interested in physics if they understood it better. When students were asked how they would use the information they learned in physics, 16 out of 19 students (55%) said that they thought physics helped them to understand and participate more fully in daily life. For instance, one female student said, "I just can't seem to get away from using it. When we make boxes at my job, when I drive a car, I'm always using physics principles." A male student said, "If I know physics, I can build a receiver or a bridge, make a mobile, be like MacGiver." Many students thought that physics would also help them pursue their goals of a college education and careers. Seven (24%) said they would use it in college and 7 said that physics pertained to their careers. These inter-

view comments corroborate the notion that a number of students wanted to understand physics rather than merely get a grade in a class. Therefore, they would be interested in learning from well-written text.

In the regular/general classes, the text had a somewhat higher standing, along with the teacher (see Table 3). These students, too, had suggestions for improving textbooks, even though they had fewer negative things to say about their own textbook. One student said that the teachers should write textbooks, because they were more knowledgeable about what students needed to learn than the usual authors. Eight students (36% of the comments) believed, as the advanced students did, that textbooks needed better, more detailed explanations and examples. Like the advanced students, they thought that textbook authors needed to pay more attention to the interests of students when posing examples. Two suggested more illustrations (9%), and 1 mentioned shorter chapters (5%).

Because they had read examples of texts they liked in another part of this study, the students also had specific comments about organizational styles they liked. Two students liked a numbered list of main points at the end of a section of text, saying that it helped them get an idea of what they needed to remember. Five students (23% of comments) liked it when texts asked a question and then discussed the answer to the question. As one student commented, "It helps me focus my attention." One student said that texts should be more careful with their end-of-chapter questions—that there should be fewer questions but that the text should be sure to ask a question about every important topic. One student suggested that texts should sometimes present made-up stories about situations to create interest. Four out of 8 students preferred text that posed questions and then explained answers over straight refutational text, although they would like refutational text if it were in a more appealing organizational format, such as a cartoon. The way the text appeared on the page seemed important to them. Short sections with spaces between them were appealing, where lots of text with no illustrations or spaces breaking up paragraphs was not. When students were asked if they liked to read the common, nonscientific beliefs that people have as well as the scientific ideas, 5 out of 8 said they did, while 3 said it was confusing or unnecessary.

When asked what strategies they used to help them learn physics, 6 students (35% of the comments) said that they paid attention in class and did not let other students distract them. Four said they studied by memorizing, testing themselves, and making diagrams and charts; 2 said they asked questions; and 4 students said they read.

If the regular/general classes were more positive about the textbook, why was text reading not effective, especially when refutational text was used? The possibility that these students would be less motivated than students in the advanced physics classes was considered. Therefore, these students were asked also to rate and explain their levels of motivation. An even higher proportion of students than in the advanced classes rated their motivation as high. When asked to explain their ratings, 8 students mentioned intrinsic factors, such as liking physics (or specific topics) and finding it

interesting, or not understanding it. Five students (45%) mentioned extrinsic factors (grades) as related to their motivation.

These students were just as motivated, if not more so, than the advanced physics students, but a larger proportion of them was more motivated by grades ("to pass" or "to pass with a B") than in the advanced classes. Because students who attended school on a regular basis were interviewed, these were probably students who were more motivated than the majority of students in these classes. A telling difference between these students and the advanced students was that these students had a harder time figuring out why physics was useful to them. Only 1 student mentioned that physics could help him understand an everyday problem (cars), and he used that example to explain why he was not interested in physics. Three students mentioned that physics would help them do better in school or get into college. Four students could think of no use for the information, and 2 believed they could help someone else learn it. Although students had ambitions to become doctors, architects, professional bowlers, scientists, nurses, and veterinarians, not one of them felt that an understanding of physical science would be useful to their careers. These students, then, may not be as motivated to truly understand physics concepts as the students in the advanced classes, because their understanding would not be as useful to them.

Students' reading strategies bear out this observation. As mentioned previously, some of the students were asked to explain their understanding of a concept, read a passage, and revise, if necessary, their prior understanding of the concept. If students could not explain or did not revise their earlier understandings, the researcher asked them to return to the text and read again portions that helped them explain the ideas. In this way, an understanding might be gained as to what difficulties students had with texts. The words might have been too difficult for students to read, but their self-reported ease in reading and observation of their oral reading suggested that students could read and understand the passages at word level. Yet, 4 of the 6 students who were asked to read these passages could not, after reading, correctly explain the targeted physics principle, nor did they revise their earlier understandings in a scientific direction. When they were directed to return to important parts of the text without specific directions about what to read, all 4 students could find the salient parts of the text passage. However, after reading the text silently a second time, none could correctly explain the scientific principle nor could they revise their earlier understandings. At that point, the researcher asked students to read specific sentences from the passage out loud, then explain what they meant. After reading out loud, 2 students could correctly explain the meaning and revised their earlier statements. For another student, each sentence had to be broken down by phrases and read a phrase at a time. A final student did not understand until the researcher explained the concept to her. Below is an account from the field notes of one encounter with a student.

> I asked J. H. to look at a diagram and choose the path of a cannon ball that was shot off a cliff. The choices were

(a) straight out, then straight down, (b) straight out, then curved down, (c) curved down, and (d) straight down. J. H. picked path (b) and explained that the force of the cannon makes it go out and gravity makes it go down. I asked what makes it begin to go down. He said the forward force *stops* and then gravity can pull it down. His answer represents a common intuitive but nonscientific idea that a force inside an object can dissipate, allowing another force to take over. I then asked him to read a refutational text describing Newton's laws of motion. This text explained that objects are influenced by outside forces and that there are no forces inside an object that stop. It also explained that objects continue to move in the direction they were launched unless acted on by another force. The most salient portion of the text for the above problem was this section: ". . . an object fired forward will move not only forward but also downward because of the constant force of the earth's gravity. In fact, the object will begin to move downward in a curved path from the moment it is fired. It will not move downward only after its forward force is used up."

When J. H. was finished reading the passage, I asked him to explain what he had learned. He said, "Forces are external," but could not expand on that idea. I asked him if he wished to revise his earlier choice in the diagram and he said, "No." I asked him if any part of the text he had read dealt with that problem, and he pointed to the last paragraph. I asked him to read that paragraph again. When he finished, he said, "An object will move not only forward, but also downward because of gravity." Because this sentence did not clear up his nonscientific understanding, I directed him to read the next two sentences out loud. When he did, he said, "Oh, then it would be this path," and pointed to path (c), which showed the cannon curving downward immediately after being launched.

Students were capable of reading and understanding the passage, as evidenced by their final understanding of the targeted physics principle. However, they did not read the passage carefully until they were finally directed to read particular sentences a second and third time, out loud. It may be that they are not used to the close reading required of science texts. If their teachers have not emphasized text reading in science classes (which their current teacher did not), they may have been using strategies for reading that were more oriented to getting main idea or gist understandings, as is sometimes emphasized in English and reading classes. Their lack of careful reading could also have been a function of their intuitive but nonscientific understanding of the principle about which they were reading. Perhaps they were reading what they expected to read rather than what was actually written.

Students who are in less-than-advanced classes may be more likely to disregard text in favor of intuition than more proficient students because careful reading is more difficult. Spiro (1980), indeed, points to the tendency for poor readers to rely too much on prior knowledge for understanding. If less proficient readers rely on prior knowledge, then text which discusses counterintuitive ideas would be especially difficult to interpret. The ideas that

students use to help them interpret the text are the very ideas the text is disputing.

Discussion

This study was initiated to investigate (1) the effects of reading refutational and regular texts, (2) the effects of other instructional practices such as lab and prediction, and (3) the effects of the interaction between texts and other practices on learning counterintuitive concepts. Pretest, posttest, observational, and interview data were collected to study these effects.

The quantitative analyses, despite lack of statistical power, indicated that prediction before a lab may have a debilitative effect on some subsequent learning of counterintuitive information about gravity, but reading a refutational text had a positive effect on the advanced students in helping them learn counterintuitive concepts about projectile motion. Reading did not help the regular/general students. Also, in most instances, neither reading, lab, nor prediction had any statistically significant effect on students' learning of counterintuitive concepts. Analyses of observational and interview data suggest the following conclusions about why the instructional practices studied were ineffective.

Students Prefer to Maintain Their Intuitive Conceptions Rather Than Undergo Conceptual Change

Students in both the advanced and regular classes were observed processing anomalous data (data that contradicts their current knowledge) in ways similar to those described by Hewson and Hewson (1984) and Chinn and Brewer (1993). Specifically, students (a) ignored data, as observed in the advanced gravity lab when students merely reiterated their predictions when they explained lab outcomes, (b) rejected data, as observed when a student refused to believe that shot and dropped arrows would reach the ground simultaneously, (c) excluded data, as did students in the advanced class when they attributed anomalous data to human error, (d) reinterpreted data to conform to expectations, as did students in the regular/general classes who attributed the slower drop of a wadded piece of paper to weight rather than air resistance, and (e) made only minor conceptual changes, as evidenced by most students who gained only two or three points on their posttest scores when compared to pretest. These findings reinforce the idea that learning counterintuitive information is more difficult than learning information that does not conflict with one's current conceptions, and support the findings of other researchers (e.g., Maria & MacGinitie, 1981; Hewson & Hewson, 1984).

Students Adopt a Task-Oriented Rather Than Concept-Oriented Approach to Laboratory Explorations and Other Learning Experiences

Observations of both the regular and advanced classes showed that students often paid more attention to getting the task done than to thinking about the concepts involved when they completed lab assignments. In both the gravity labs and the projectile motion labs, the procedures became cumbersome for students. The regular/general students had

difficulty reading the spring scale in the gravity lab and had difficulty performing the dart tasks in the projectile motion lab. The advanced students may have been more concerned with protecting their egg in the gravity experiment (where they had to keep it from breaking when dropped) than they were with learning principles of gravity. In the projectile motion lab, they had difficulty obtaining accurate data to use in calculations. When the procedures became difficult, students seemed to adopt a nonconceptual approach to the task. For example, the advanced students used trial-and-error to estimate the final outcome of the projectile motion experiment, and the regular/general students copied each others' work in the gravity experiment.

Perhaps, also, this task-oriented approach is a function of students' confusion about the principles involved in conceptual understanding. It was supposed that the students in the regular/general classes in particular adopted task-completion procedures when concepts were highly counterintuitive. In support of this idea, their nonsensical explanations and copying in the gravity experiment, and the targeted students' gist-oriented, inaccurate reading of counterintuitive text were noted. Observations of off-task behavior during labs also suggest that many students really did not persist in learning the counterintuitive material. Furthermore, several students in the regular/general classes commented that paying attention and ignoring other students were important but difficult parts of learning information in science class. All these pieces of evidence suggest that these students, in the face of conceptual difficulty, opted for completing the task rather than understanding it.

Although students interviewed in the regular/general classes reported even higher levels of motivation than the advanced classes for education and for learning physics, these students mentioned a higher proportion of extrinsic factors in their motivation than students in advanced classes and could think of fewer uses for physics knowledge than the advanced students. Dweck (1986) ties intrinsic motivation to task persistence, and explains that students who are motivated extrinsically may not persist in understanding tasks but would rather opt for task completion. Perhaps, too, students who see no value in learning physics except to pass the class would be less likely to care about understanding; they can see no way to use the information in the future. Students in the advanced classes were more often capable of seeing uses for physics information; therefore, they may have been more motivated to understand. These observations support findings from a previous study (Hynd, McNish et al., 1994).

Students in the Advanced Classes Had More Resources for Understanding Counterintuitive Concepts Than Students in Regular/General Classes

In the advanced classes, students relied on each other to help them learn counterintuitive information. Observations of labs and other opportunities for student-to-student interactions showed that some students were regarded as knowledgeable about physics. These expert

students, like the teacher, were relied upon to help students who needed it. In the regular/general classes, on the other hand, students were generally distrustful of each other. Students commented that the other students in class needed to be avoided if learning were to take place.

Advanced students also responded to the refutational text, while in the regular/general classes, text—refutational or otherwise—did not make a difference in learning. When the regular/general students read text under supervision, they either failed to comprehend or misread text that was counterintuitive, allowing them to maintain their intuitive conceptions. Therefore, while text was a viable way for advanced students to learn counterintuitive information, it was not for regular students, at least not without instruction in reading and teacher support while reading.

Textual Materials Used in Science Classes Could Be Improved

Students in the advanced classes had interesting observations about the current textbook, and students in all classes had wise recommendations for improving science text. Students noticed and were bothered by the lack of fit between their knowledge, language, and interests and those of the textbook. Students wanted texts that anticipated their levels of understanding, used language they understood, and used examples to which they could relate. Furthermore, students were interested in fuller, more detailed explanations of physical phenomena. W. Y., for instance, was bothered that he knew the way gravity acted on objects but had never been told why. Therefore, gravity remained counterintuitive. Going through a year not understanding information that is supposed to be learned has to be debilitating to one's motivation. Indeed, students expressed their frustration at not learning from text and their concurrent lack of motivation. Students also wanted to see text organized in reasonable ways, so that explanations would be easier for them to find (advanced students), and so students could better focus their attention on salient information (regular/general students). These comments validate the observations of Beck, McKeown, and Gromoll (1989), and Britton and Gulgoz (1991), who decried the lack of adequate explanations in textbooks and the lack of fit between students' knowledge and text explanations.

This study considered the failure of current instruction using text and lab in helping students construct scientifically acceptable explanations for physical phenomena. Students maintained nonscientific ideas despite attempts to engage them in constructing scientific ideas through lab, and the regular/general students maintained their ideas despite being provided with textual explanations. The reasons for this failure, as shown, are complex and include both motivational and cognitive explanations. Even though the teachers were concerned with their students' understanding and were interested in helping students learn the processes and products of science through lab and discovery, their lab instruction failed to focus students' attention on salient information and allowed students to complete tasks without conceptual understanding. Students did not create or discover scientifically viable explanations

for the phenomena they observed. Although many students did make gains between pre- and posttests, these gains in understanding did not, on the whole, come from lab or text. Most likely, they came from the teachers' direct explanations and discussions of the principles involved. Do these results mean that instruction must be more direct and less intuitive? Does direct explanation of the scientific reasons for physical phenomena fly in the face of our current constructivist thinking? These questions should be the focus of ongoing research.

The results of this study provide fodder for improving instruction. Based upon these results, the authors are now working at making labs more conceptual by involving students in designing the labs, as well as studying adaptations of texts that have incorporated students' suggestions. Additionally, ways of making physics more relevant to students who do not anticipate careers in science and avenues for instructing students in reading science texts are being explored. Finally, methods for confronting students' nonscientific conceptions in more powerful ways are being addressed. These methods include extending the length of instruction in counterintuitive concepts, allowing students to express their ideas and questions more fully during class discussions, relying on demonstrations and discussion rather than just lab to clarify concepts, and using several different sources of information for confirmation of concepts (e.g., more than one text, film, lab, teacher, etc.).

References

Alvermann, D. E., Smith, L. C., & Readence, J. E. (1985). Prior knowledge activation and the comprehension of compatible and incompatible text. *Reading Research Quarterly*, *20*, 420–436.

Ausubel, D. T. (1968). *Educational psychology: A cognitive view*. New York: Holt, Reinhart, & Winston.

Beck, I. L., McKeown, M. G., & Gromoll, E. W. (1989). Learning from social studies texts. *Cognition and Instruction*, *6*, 99–158.

Britton, B. K., & Gulgoz, S. (1991). Using Kintsch's computational model to improve instructional text: Effects of repairing inference calls on recall and cognitive structures. *Journal of Educational Psychology*, *83*, 329–345.

Chinn, C. A., & Brewer, W. OF. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research*, *63*(1), 1–49.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education*, *5*, 61–84.

Dweck, C. (1986). Motivational processes affecting learning. *American Psychologist*, *46*, 1040–1048.

Garner, R., Gillingham, M. G., & White, C. S. (1989). Effects of "seductive details" on macroprocessing and microprocessing in adults and children. *Cognition and Instruction*, *6*, 41–58.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. New York: Aldine Press.

Guzzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Meta-analysis of instructional interventions from reading education and science education to promote conceptual change in science. *Reading Research Quarterly*, *28*, 116–161.

Hewitt, P. G. (1987). *Conceptual physics*. Menlo Park, CA: Addison Wesley.

Hewson, P. W., & Hewson, M. G. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science*, *13*, 1-13.

Hynd, C. R., Alvermann, D. E., & Qian, G. (1993). *Prospective teachers' comprehension and teaching of a complex science concept* (Reading Research Report No. 4). Athens, GA: NRRC, Universities of Georgia and Maryland College Park.

Hynd, C. R., McNish, M., Qian, G., Keith, M., & Lay, K. (1994). *Learning counterintuitive physics principles: The effects of text and educational environment* (Reading Research Report No. 16). Athens, GA: NRRC, Universities of Georgia and Maryland College Park.

Hynd, C. R., McWhorter, Y., Phares, V., & Suttles, W. (1994). The role of instructional variables in conceptual change in high school physics topics. *Journal of Research in Science Teaching*, *31*, 933-946.

Maria, K., & MacGinitie, W. (1981, December) *Prior knowledge as a handicapping condition*. Paper presented at the annual meeting of the National Reading Conference, Dallas, TX.

Marshall, N. (1991, December). *A case study of conceptual change in preservice elementary teachers*. Paper presented at the annual meeting of the National Reading Conference, San Antonio, TX.

Newport, J. F. (1990). What's wrong with science textbooks? *Principal*, *69*(3), 22-24.

Oldfather, P. (1993). What students say about motivating experiences in a whole language classroom. *The Reading Teacher*, *46*, 672-681.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*, 211-227.

Schymansky, J. A., Yore, L. D., & Good, D. W. (1991). Elementary school teachers' beliefs about and perceptions of elementary school science, science reading, science textbooks, and supportive instructional factors. *Journal of Research in Science Teaching*, *28*, 437-454.

Snyder, T. (1993). *The effects of cooperative and individual learning on student misconceptions in science*. Unpublished doctoral dissertation, Arizona State University.

Spiro, R. J. (1980). Constructive processes in prose comprehension and recall. In R. J. Spiro, B. C. Bruce, and W. F. Brewer (Eds.), *Theoretical issues in reading comprehension* (pp. 245-278). Hillsdale, NJ: Erlbaum.

Yore, L. D. (1991). Secondary science teachers' attitudes toward and beliefs about science reading and science textbooks. *Journal of Research in Science Teaching*, *28*, 55-72.

Appendix

Examples of Test Questions

Gravity Tests

T/F:

A recent TV commercial shows 2 biscuits being dropped from a one-story building. One biscuit is heavier than the other. If air resistance were not taken into account, the light biscuit would hit the ground first.

An acorn and a leaf fall off a tree at the same time from the same spot. Because it is heavier than the leaf, the acorn will hit the ground first.

Without air resistance, all objects fall at the same accelerating rate.

Short answer:

When objects are dropped straight down, what determines how fast the objects fall?

Under what conditions will two objects fall at the same speed as each other?

Which will hit the ground first—a wadded up or a flat piece of paper? Why?

Application:

You have two blocks of the same size. One block weighs 2 pounds and the other block weighs 4 pounds. Describe what will happen if the two blocks are dropped at the same time from the top of the Washington Monument. Which block will hit the ground first? Explain your answer.

Balanced Forces Tests

T/F:

A book is resting on a table. The book exerts a force on the table, but the table does not exert a force on the book.

If you hold an apple in the palm of your upturned hand, your hand exerts a force on the apple.

Any time an object is at rest, it has no force acting on it.

Short answer:

Explain what force or forces are working when a parachutist, with his parachute open, falls to the ground.

What causes an airplane to stop moving faster and maintain a constant speed?

Explain what force or forces are working when a person sits on a stool.

Application:

A ball that rests on a table is not moving. Explain why the ball stays in one place.

Using physics principles, explain what would need to happen to get the ball moving, explaining the force or forces responsible.

Projectile Motion Tests

T/F:

If you want to drop a golf ball while you are walking so that it will hit a target marked on the floor, you should drop the ball before you reach the target.

When a bullet is fired forward, the effect of gravity on its downward motion is delayed for a while by the object's forward motion. In other words, the bullet will fly straight for a while before beginning to fall.

For an object launched horizontally, the path is straight out, then straight down.

Short answer:

A person is walking forward at a brisk pace carrying a stone at shoulder height. Explain where the stone would fall in relation to the point where it was dropped. Why?

Explain why an object stops or changes direction.

Application:

Ignoring the resistance of air, choose the path that would be taken by a cannonball shot horizontally (straight out) from the cannon. Circle your answer. Then write an explanation of the reasoning behind your answer. (Drawing is shown of a cannon on a cliff and four possible paths the cannonball could take.)

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